THE EFFECT OF FORCED ACTIVITY ON THE MAZE PERFORMANCE OF WHITE RATS

BY
WENDELL L. GRAY

A DISSERTATION SUBMITTED TO THE BOARD OF UNIVERSITY STUDIES OF THE JOHNS HOPKINS UNIVERSITY IN CONFORMITY WITH THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

1933

BALTIMORE, MARYLAND
1937

Reprinted from THE JOURNAL OF COMPARATIVE PSYCHOLOGY
1937, Vol. 23, No. 3

Reprinted from THE JOURNAL OF COMPARATIVE PSYCHOLOGY
Vol. 23, No. 3, June, 1937

THE EFFECT OF FORCED ACTIVITY ON THE MAZE PERFORMANCE OF WHITE RATS[1]

WENDELL L. GRAY
Department of Psychology, The Johns Hopkins University

Received for publication October 19, 1936

STATEMENT OF PROBLEM

The series of experiments here recorded constituted primarily an investigation of the effect of compulsory activity on the maze learning ability of albino rats. A secondary purpose of the experiments was to study the effect of forced activity on selection and consumption of food by rats. The results obtained in the experiments on food consumption will be presented in a separate report at a later date.

SUMMARY OF PREVIOUS RELATED STUDIES

A survey reveals that, while the literature on spontaneous activity of animals, particularly the white rat, is quite extensive,[2] very few investigations of forced activity and its effects have been undertaken. Of these, the following appear to have sufficient bearing on the present problem to warrant brief description. For the most part, the investigators have been concerned with the effect of fatigue on growth and health of the animals.

[1] The experiments here described were carried out in the Psychological Laboratory of the Johns Hopkins University. This report is a portion of a dissertation submitted to the Board of University Studies of the Johns Hopkins University in conformity with the requirements for the degree of Doctor of Philosophy.

The author wishes to express sincere appreciation to Professor Knight Dunlap for his encouragement and valuable criticism, and to Dr. Roy M. Dorcus for his suggestions concerning the problem and supervision throughout this investigation.

[2] Representative studies on spontaneous activity of white rats have been reported by the following investigators: Durrant, E. P. (14, 15); Gans, H. M. (16); Hitchcock, F. A. (18, 19); Hoskins, R. G. (20, 21); Richter, C. P. (30, 31); Shirley, M. (34, 35); Slonaker, J. R. (36, 38, 39, 40); Wang, G. H. (47). (Complete titles and references are presented in the bibliography.)

R. UNIV. BIBLIOTHEEK LEIDEN

Mention will first be made of certain studies in which species other than white rats served as experimental subjects.

In 1897, Morpurgo (25) reported an experiment in which dogs were trained to run in a treadmill. The experimenter found that this exercise resulted in a marked increase in the size of the sartorius muscle and that this growth was a matter of cell enlargement rather than cell multiplication.

Nichols and Spaeth (27) experimented with guinea pigs in an attempt to demonstrate a relationship between fatigue and susceptibility to pneumococcus infection. Guinea pigs were forced to run until exhausted in revolving wire cages driven by a motor. Lethal injections of Type I pneumococcus infection were given to these exhausted animals and to control animals. It was found that fatigue definitely increased the resistance of the cavvies to this infection.

Spaeth (42) later used a similar type of activity cage in his investigation of the supposed relation between good physical condition and natural resistance to infection in guinea pigs. Fatigue was found to correlate positively with high resistance to infection.

Vallardi (46) fatigued guinea pigs by means of a moving carpet and found that the fatigued animals died sooner than the controls when inoculated with typhoid.

Bailey (3) has reported that compulsory activity, resulting in exhaustion, lowered resistance of rabbits to infection by pneumococcus, whereas prolonged exercise increased it.

Abbot and Gildersleeve (1) also experimented with rabbits and observed that a reduction of the opsonic index occurred after forced exercise.

More closely related to the present investigation than the experiments described above is a somewhat larger group of studies in which the white rat was used as the experimental animal.

One of the earliest of all experiments in which forced activity was employed was that of Charrin and Roger (8, 9), reported in 1890. These workers found that compulsory exercise in a revolving drum definitely increased the susceptibility of rats to anthrax and quarter-evil.

Another early series of activity studies was published by Boinet

(4, 5) in 1895. Boinet investigated the lowering of resistance to fatigue resulting from excision of the suprarenal capsules. Rats were exhausted by running in a cylindrical revolving squirrel cage, measuring about 20 cm. in diameter. This cage was steadily rotated at the rate of 22 revolutions per minute. It was found that loss of the suprarenal bodies lowered resistance to fatigue brought on by muscular activity.

In 1922, Oppenheimer and Spaeth (28) published the results of an investigation of the relation between fatigue and the susceptibility of rats towards a toxin and an infection. These experimenters made use of activity drums similar to those first described by Richter (32). These drums were 12 inches in diameter and 9.5 inches wide. They were motor driven. The criteria set up for fatigue were inability to maintain balance in the drum and failure to respond to auditory and tactual stimuli. It was found that the fatigue tended to increase the rats' resistance to subcutaneous injections of tetanus toxin. Likewise, such fatigue definitely increased the resistance of white and hooded rats to injections of pneumococcus infection.

Keith and Mitchell (24), in 1923, reported an experiment on the effect of compulsory exercise on vitamin requirements. They wished to verify the prevalent impression that the ill effects of vitamin deficiency are more severe and appear sooner under the strain of muscular exercise. Their procedure was to compare the condition and weight changes of exercised and unexercised rats on rations which were deficient in vitamin A or vitamin B. Rats were divided into pairs. One of each pair was exercised daily in a revolving cheese box rotating at 13 revolutions per minute, and the other was used as a control.

The experimental results indicated that the amount of exercise employed did not uniformly affect the growth curves or the well-being of the rats either on complete rations or on rations lacking in vitamin B. The exercise hastened the appearance of the symptoms of vitamin A deficiency and resulted in the premature death of young animals receiving insufficient amounts of this vitamin. No clear evidence was obtained that the amount and type of muscular work imposed on the rats in this test affected their requirement for vitamin B.

Forced activity was employed by Slonaker and Robertson (41) in their study of the effect of compulsory work during gestation on the mother and young. Pregnant females were compelled to run a distance in excess of that which they would voluntarily run while pregnant. In this way, data could be obtained on the effect of increased work on the length of the gestation period, on the size and number of young, and on the weight and health of the mother. Eight animals were used, 4 of which received forced activity. The amount of forced running varied from 2 to 7 hours daily.

Among the interesting conclusions drawn from this experiment were the following: (1) the pregnant rats lost more weight during forced exercise than did pseudo-pregnant or non-pregnant rats; (2) the average food consumption of exercised pregnant rats was greater than that of exercised non-pregnant and pseudo-pregnant rats; (3) a close relation was found between the weight lost and the amount of forced exercise; (4) the amount of food eaten, however, was not an accurate measure of energy expenditure, energy being measured by number of revolutions traveled; (5) the younger rats were more affected by forced exercise than the older animals; (6) forced activity during gestation resulted in a decrease in the voluntary activity of the mother, at least during the first days of lactation; (7) in several cases, forced work appeared to be the cause of death during gestation and pseudo-pregnancy.

In 1926, Boycott and Price-Jones (6) published an experiment on the influence of fatigue upon infection. Rats were fatigued in revolving drums similar to those described by Oppenheimer and Spaeth (28). The rat was considered fatigued when it lay on its back in the bottom of the drum without making an effort to stand. These authors maintained that the only objective measure of fatigue is the pronounced fall in body temperature which accompanies exhaustion in rats. The results of the experiments were interpreted as showing that fatigue has no effect on the mortality of rats after inoculation with Gaertner's bacillus, and that the rat's natural resistance to tuberculosis is not lowered by repeated exhaustion.

The influence of forced running on the growth of very young

white rats has been investigated by Price-Jones (29). Newly-weaned animals were exercised in drums, 12 inches in diameter, made of one-tenth inch mesh brass wire-gauze, turned by a motor at 8 to 9 revolutions per minute. Exercise was given daily, except Sundays. Control groups were established by the split litter method. The periods of observation extended from 36 to 52 days. The rate of growth of the unexercised rats was found to be from 1.44 to 1.25 times that of the exercised rats. Price-Jones concluded that "exercise retards the increase in weight and length of the body and of the skeleton."

Seham and Seham (33) measured the effect of forced exercise on the general behavior, voluntary activity, and body weight of albino rats. During the period of forced exercise a marked decrease occurred in the voluntary activity of the experimental rats as compared with that of the controls. Accompanying the reduction in voluntary activity, there appeared a loss in weight or a decreased gain in weight, increased blinking, irritability, and restlessness. No pathological changes could be found in gross or microscopic examinations.

One of the more recent and more comprehensive experiments in the field of forced activity was that by Corey (10), in which he studied the relationship between compulsory physical exercise and the ability of the white rat to learn and relearn an elevated skeleton maze. Since Corey's investigation is comparable in many respects with the present study, it will be presented in some detail, and certain aspects of it will be considered in other portions of this report.

The apparatus used for forcing activity consisted of a rotating wire cage or drum, divided into 4 sections, each section accommodating 2 animals. Thus, 8 rats could be exercised simultaneously. The drum was driven at the rate of 12 revolutions per minute. At this rate, the exercise of the rats was equivalent to covering a linear distance of about 4500 feet per hour. Some of the animals had difficulty in learning to run in the drum, but the experimenter believed that the rats were being exercised whether they ran or were carried around clinging to the wire periphery. Learning was measured in total number of errors made during the series,

total number of trials, total time spent on the maze, and time spent in actual running. Retracing errors were not considered. Three experimental and three control groups of 31 animals each, two months old, were used. Group I was given one hour of exercise; group III, three hours; and group V, five hours of exercise, daily.

The daily procedure for the exercised rats was: (a) testing on the maze; (b) exercise in rotating drum; and (c) feeding. Food was employed as the incentive to learning for both groups.

The retention of the rats was measured in terms of ability to relearn the maze after an interval of 14 days. According to the measures of learning adopted, the exercised rats proved superior to the controls, but the difference between the scores was statistically significant according to only one criterion. The superiority of the exercised rats over the controls did not increase as the amount of forced exercise was increased. This held true even for the group which was exercised for five hours each day. Corey concluded that "compulsory physical exercise did not have a consistent or noticeably peculiar effect upon learning which involves the activity of the whole body when rats were used as subjects and an elevated skeleton maze as a test of learning ability."

The description of Corey's experiment completes this brief survey of the previous studies of animal activity that are related to the present investigation.

ANIMALS USED IN THE PRESENT EXPERIMENT

Forty-eight albino rats, bred from stock maintained by the psychological laboratory of the Johns Hopkins University, were used in the present investigation. Throughout the experiment, the animals were handled only by the experimenter and were kept under favorable living conditions. A modified Steenbock diet (43) served as the regular ration. The type of apparatus employed and the comparatively elaborate procedure followed necessitated intensive experimentation with a small number of animals at each stage of the investigation.

Six separate groups were employed consecutively, with a slightly different procedure being followed for each group. Each

of the six groups was composed of 8 animals, 4 of which were designated "activity" animals (forced exercise given) and 4 were "controls." The animals of the six groups varied in age and sex, but for any given group the activity and control rats were equated with respect to these factors and with respect to litter, weight, and spontaneous activity. Specific data concerning the composition of the groups are presented in table 1.

TABLE 1

Composition of groups

GROUP	NUMBER OF RATS		AGE-RANGE	SEX
	Control	Activity		
I	4	4	110–125 days	Males
II	4	4	150–165 days	Males
III	4	4	97–108 days	Males
IV	4	4	215–225 days	Females
V	4	4	130–150 days	Females
VI	4	4	150 days	Males

* One activity animal died before the learning series was completed.

APPARATUS

A. Maze. The experiments were carried out with a six-section, multiple-U maze, a detailed description of which has been published previously (12). Warner and Warden (49) have compared this type of maze with many other types and have judged it highly reliable.

The floor plan of the apparatus is shown in figure 1. The maze was constructed of one half inch redwood. The pathway throughout was 4 inches wide and the "straightaways" were 18 inches long. The sides of the maze pathway were 12 inches high. A starting box, 8 inches wide and 10 inches long, was located at one end and a goal box, 10 inches wide and 12 inches long, at the other. The total distance of the true pathway from the starting box to the escape box was approximately 16 feet. Drop doors could be attached at each of the six units of the maze pathway to prevent retracing. These doors could be operated by the experimenter from a distance. In certain of the experiments, drop

doors were used to separate every section of the maze. In other experiments, only three drop doors were used. The maze pattern (R–L–R–R–L–L), shown in figure 1, was the same for all experiments except that with group II. The pattern was exactly reversed for this group.

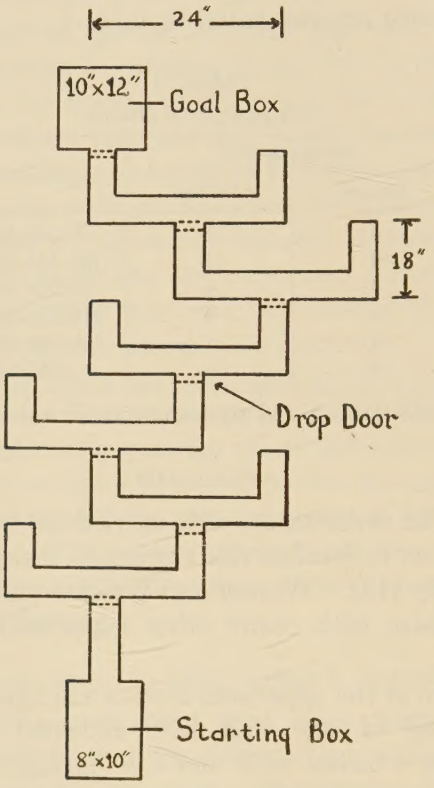

FIG. 1. DIAGRAM OF MAZE

Food was used as the incentive to learning for the animals of groups I, II, and III. Electric shock served as the incentive to learning for succeeding groups. When the latter type of incentive was employed, the bottom was removed from the maze, and the entire structure rested upon a large copper-wire grid, the parallel wires of which were one fourth inch apart. The wires of

the grid served as the floor of the maze pathway from the starting box to the entrance of the escape box (goal box). The arrangement was such that when running, walking, or resting, the animals received a shock when in contact with two adjacent wires.

B. *Activity cages.* The cages in which forced activity was administered were originally designed to measure spontaneous activity. They were essentially similar in general plan to an apparatus first employed by Stewart (44). A modification of Stewart's activity cages was described by Slonaker (37) in 1908. Richter and Wang (32) have made use of a comparable type of activity drum.

A revolving drum and a small living compartment attached to opposite sides of an upright partition made up a single unit. The entire cage was constructed of sheet metal and quarter-inch wire mesh. An opening, with a sliding door built into the partition, connected the living compartment and the revolving drum. The revolving drum was 14 inches in diameter and 4 inches wide. The activity drum rotated easily on ball-bearings. A Veeder cyclometer, located on the face side of the upright partition, summated complete revolutions of the drum in either direction.

Spontaneous activity records, obtained for purposes of equating groups, were secured with the cages as described. In order to administer forced activity, 4 of the cages were aligned side by side so that a single belt, driven by a small motor, could rotate all 4 drums simultaneously. The motor was provided with reduction gears and detachable driving wheels, making possible two different rates of forced rotation. The two speeds used in the experiment were: (1) 10 revolutions per minute, and (2) 20 revolutions per minute. When large amounts of forced activity were given, the peripheries of the drums were lined with rough linoleum. The linoleum served to eliminate foot injuries to the animals and to prevent them from riding the drum by clasping the wire mesh.

C. Living cages. Individual living cages were provided for all animals during preliminary periods and during the actual learning experiments. The cages were cylindrical, 12 inches high and 10 inches in diameter. They were made of galvanized sheet

metal and quarter-inch wire mesh. Each cage was provided with a metal food container and a glass water holder.

D. Electrical apparatus. In constructing the shock apparatus, measures were taken to eliminate differences in intensity of stimulation resulting from differences in skin resistance of the animals. High voltage, with high external resistance in the circuit, reduced

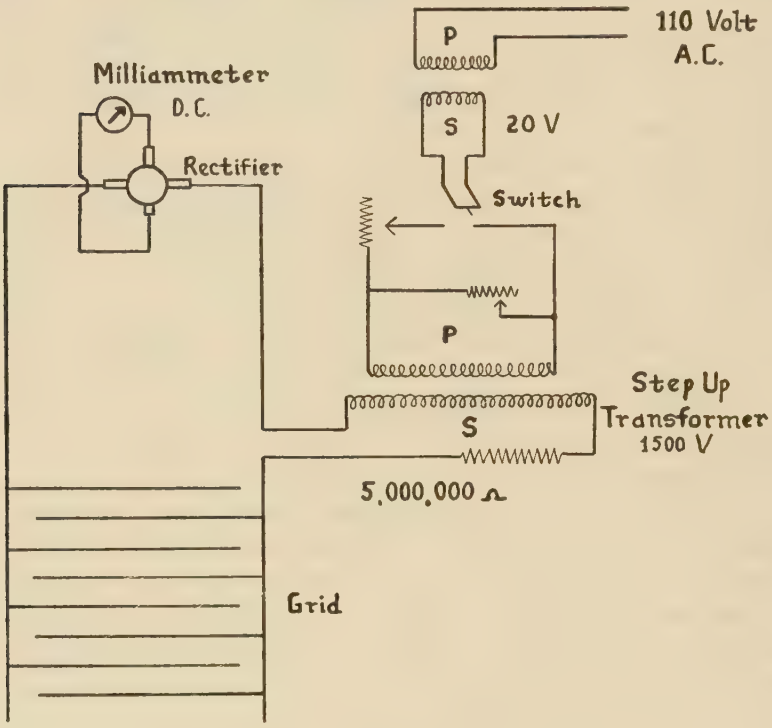

Fig. 2. Diagram of Electrical Apparatus

these differences to a minimum. A diagram of the electrical set-up is given in figure 2.

This apparatus has been described in detail by Dunlap (13). Electric current was obtained from the 110-volt A.C. lighting circuit. The secondary coil of a step-up transformer, supplying 1500 volts, was connected in series with the maze grid and wire-wound resistances totaling 5,000,000 ohms. A sensitive D.C.

milliammeter in a loop from a copper-oxide rectifier could be thrown in the circuit at will. This apparatus furnished approximately 0.00015 ampere of current.[3]

PROCEDURE AND RESULTS

For a period of five days before being started on the maze problem, the rats of each group were maintained in activity cages. During this period, spontaneous activity records were obtained and food consumption was measured. Four of the 8 animals in each group were thereafter used for controls; the other four, the "activity" animals, were forced to exercise daily in activity cages during the maze-learning period.

The regular procedure with the activity (forced exercise) animals was to place them in the maze immediately after a prescribed period of forced running. One maze trial was given daily for at least 20 days. The control rats were treated in the same manner as the activity animals, except that they were not forced to run in the activity cages. The amount of forced exercise given the activity animals was not constant for all six groups. Statement of the exact amount of forced exercise for each group will be noted as the results obtained with the separate groups are discussed in the pages following.

The animals of groups I, II, and III were trained with food as the incentive to maze learning. After traversing the maze each day, they were allowed to feed for 4 minutes in the goal box, from which they were then removed and fed for 20 minutes in individual feeding compartments. Observations on the maze performance and on the body weight of these three groups during the learning period suggested that some type of motivation other than hunger was to be preferred. Since the activity animals showed a much greater loss in weight than the control animals, it might be argued that any difference found between the control and activity animals in learning could be attributed to inanition rather than forced activity. For this reason, escape from punish-

[3] Somewhat similar pieces of apparatus have been described by Jenkins, Warner, and Warden (23); Howells (22); and Muenzinger and Mize (26).

ment (electric shock) was used as the motive to learning with groups IV, V, and VI. The floor of the original maze was removed and the maze placed on a large copper-wire grid. In this situation, the rat received a shock continuously from the time it was placed in the maze until it entered the escape box at the end. With this arrangement, unrestricted feeding was permitted the animals. Food was available at all times except when the animal was in the maze or in the activity cage. The success of the punishment type of motivation for animal learning was highly gratifying, and it is probable that motivation for control and activity animals was more nearly equal under these conditions than when hunger was the motive.

The experimental results will be treated for each of the six groups individually. In addition, a brief discussion will be given of the findings when the results on all six groups were combined for statistical treatment.

The data, in the form of errors made and time consumed for trial, will be presented in tabular form for each group and for the groups combined. Learning curves plotted from the average daily scores will be presented for only groups I and IV and for the combined groups. These are given as representative of the relative performances of the activity and control animals of all groups.

In discussing the results, it will be noted that more importance is attached to error scores than to time scores as a criterion of maze learning. This evaluation of error scores as a more reliable measure of maze performance than such measures as time scores and number of trials is in accord with the findings of Warden and Schneck (48) and Tolman and Nyswander (45).

A. Group I. Group I was composed of 8 male rats, ranging in age at the beginning of the experiment from 110 to 125 days. The animals were paired into control and experimental groups on a basis of age, litter, and spontaneous activity. The voluntary activity records were obtained during a five-day period prior to the beginning of the learning experiment. Spontaneous activity was thought important, since the amount of forced activity tolerated may have some direct relation to the amount of activity

normally taken. Both control and experimental animals were given one trial daily on the six-section, multiple-U maze. The maze pattern for the group, and for all other groups except group II, was: R–L–R–R–L–L. Drop doors were located at the ends of sections 1, 3, and 5 of the maze. Care was taken to work with the animals at approximately the same hour each day.

The experimental animals were forced to run 600 revolutions in the activity drums daily, at the rate of 10 revolutions per minute. The forced exercise was given just before the daily maze trial. Food was used as the incentive for maze running. All animals were allowed to feed for 4 minutes in the goal box of the maze after completing the run. They were then removed to individual feeding compartments, where they were permitted to feed for 20 minutes longer, and subsequently were removed to individual living cages, where they remained without food until the next day. The standard learning series consisted of 20 trials. In previous experiments (11, 12) using this type of maze, it was found that rats showed a fair degree of mastery in 20 trials.

The data obtained with group I are presented in table 2 and figures 3 and 4. The average error and average time scores made by the control and the experimental animals for each trial are given in table 2. The same data are shown in graph form in figures 3 and 4. Inspection of the data in figure 3 reveals that learning occurred in both groups, but that there was no striking difference between the performances of the control and experimental animals. Although the activity rats made somewhat better error scores during the first 8 trials, this superiority was not marked, nor was it maintained consistently. Both the experimental and control groups showed considerable fluctuation in average errors throughout the series. The error curves for the two groups tend to approximate each other during the last 5 trials. The error curve for the activity group remains below that for the control group for the greater part of the experiment, but the difference is not significant on account of the change in the relative number of errors in the various stages of learning.

From figure 4, it is also evident that learning occurred in both groups of animals insofar as time scores may be used as a criterion.

Both the activity and the control animals were relatively slow in the first trial. The curves for both groups drop at about the same rate. By the fifth trial, approximately 28 seconds were required to run the maze, and after the thirteenth trial there was little improvement in time scores. The activity animals consumed more time than the control animals on the first trial and were a little slower and more variable throughout the middle of

TABLE 2

Average time and errors for group I

TRIAL	TIME IN SECONDS		ERRORS	
	Activity	Control	Activity	Control
1	142.2	118.7	3.00	3.50
2	61.5	57.0	3.00	3.50
3	59.0	39.5	3.00	2.75
4	42.7	46.5	3.00	4.25
5	27.7	29.5	2.00	3.75
6	34.2	23.2	2.50	3.00
7	22.5	31.2	1.25	3.25
8	31.0	20.2	1.00	1.75
9	29.2	20.0	2.50	2.25
10	37.0	21.0	2.25	2.50
11	20.2	16.2	1.75	2.00
12	30.7	14.7	2.25	1.00
13	15.9	14.5	1.25	2.00
14	10.2	14.1	0.75	2.00
15	12.4	11.1	0.50	1.25
16	13.0	10.3	1.00	1.00
17	9.6	12.2	0.50	1.50
18	11.8	12.0	1.00	0.75
19	10.2	11.3	1.00	1.00
20	13.1	11.5	1.00	0.75

the series. In the last 8 trials, the average performances of the two groups remained constant and were practically equivalent.

According to time scores, the control group might be judged slightly superior to the activity group, but according to error scores, an equal, or greater, degree of superiority is shown by the activity animals. As noted earlier in this report, it is believed by the experimenter, along with Tolman and Nyswander (45),

that error scores provide a more reliable criterion than time scores in this type of maze learning.

Careful consideration of the results obtained with Group I necessitates the conclusion that forced activity of the amount and at the speed given had no marked effect on maze learning.

B. Group II. Since it was found with group I that the amount of forced activity given had no appreciable effect on the maze learning of 4 animals, it was suspected that either the rate was too

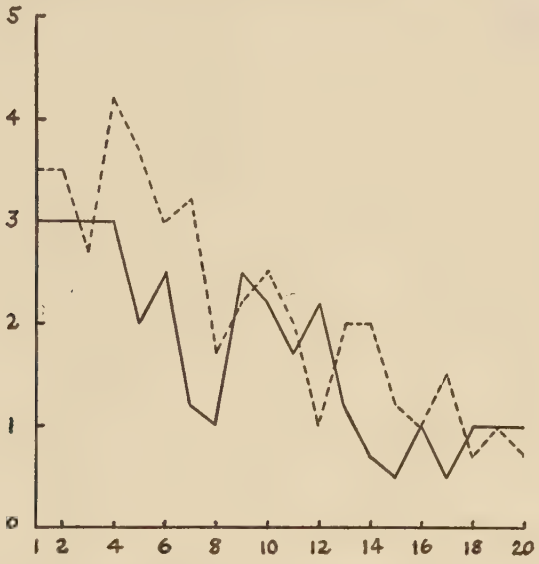

FIG. 3. AVERAGE ERROR CURVES FOR GROUP I

Successive trials are indicated on the abscissa. Average error scores per trial are shown along the ordinate. The solid line represents the average number of errors per trial made by the activity animals. The broken line represents the average number of errors per trial made by the control animals.

slow or the amount given was too small. Preliminary work showed that rats could be forced to run without ill-effect in the drums at the rate of 20 revolutions per minute. It was decided, therefore, to use a faster rate of forced running with another group of animals and to train them on a similar maze pattern. The animals composing group II were males, approximately 150 days old when the experiment was begun.

The same maze was used, but the pattern was reversed. The

correct pathway in the first experiment was R–L–R–R–L–L; in the second experiment, it was L–R–L–L–R–R. The activity animals were given 600 revolutions of forced activity per day at the rate of 20 revolutions per minute. This was double the rate

FIG. 4. AVERAGE TIME CURVES FOR GROUP I

Successive trials are indicated on the abscissa. Average time scores (in seconds) per trial are shown along the ordinate. The solid line represents the average time per trial consumed by the activity animals. The broken line represents the average time per trial consumed by the control animals.

used in the preceding experiment and meant that the animals had to do at least as much, if not more, work in one half the time. When the experiment was begun, the plan was to give each animal 20 trials on the maze. The experiment was extended, how-

ever, for a short period beyond the twentieth trial to discover whether greatly increased amounts of forced exercise would produce some definite effect on maze running. Three additional trials were given, the activity being increased to 1200 revolutions on the twenty-first and twenty-second days and to 1500 revolutions on the last day.

TABLE 3

Average time and errors for group II

TRIAL	TIME IN SECONDS		ERRORS	
	Activity	Control	Activity	Control
1	163.5	41.2	2.50	3.25
2	80.5	25.5	2.75	3.00
3	50.7	26.0	2.00	1.75
4	24.7	18.0	3.00	1.75
5	15.7	13.7	1.25	0.50
6	14.2	18.2	0.25	1.50
7	18.2	16.7	1.50	1.25
8	21.2	15.0	2.00	0.75
9	12.2	11.7	1.25	0.75
10	11.3	14.7	0.50	1.00
11	11.2	11.5	1.00	0.50
12	9.2	9.8	0.50	0.50
13	8.9	10.6	0.75	0.50
14	7.8	9.7	0.25	0.50
15	8.0	8.5	0.50	0.25
16	8.0	7.7	0.25	0.25
17	7.3	8.7	0.00	0.50
18	8.3	7.3	0.50	0.00
19	7.5	9.3	0.25	0.75
20	7.3	7.3	0.25	0.00
21	7.4	8.7	0.00	0.50
22	7.5	9.6	0.00	0.50
23	8.9	7.3	0.75	0.25

The average time and error scores for the control and activity animals of group II for the 23 trials are given in table 3. The animals of both groups showed progressively throughout the series a marked reduction in time and elimination of errors.

The activity animals made a slightly better average error score on the first and second trials, but the superiority was not great. After the first trial, the average error scores made by the two

groups tended to be approximately equivalent, although the activity animals, during the first half of the series, showed somewhat greater variation. From the tenth to the twentieth trial, very few errors were made by either the activity or the control group. No marked difference in performance, as measured by errors, was detectable during the second half of the maze series. This was true also for the three extra trials, the activity group showing slightly superior performance on the twenty-first and twenty-second trials and making relatively few errors on the twenty-third trial, when forced activity was greatly increased.

From the time records for group II, it is apparent that learning occurred, since the time required to run the maze was progressively reduced. The activity animals were much slower than the control animals on the average in the first trials. This difference was probably due to fatigue and to emotional disturbance produced in the activity animals by the forced running. The animals had had no experience with forced exercise in the activity drums prior to the experiment proper. From the fifth trial to the end of the series, the time scores for the two groups are very nearly equal. There is a gradual trend toward a decrease in time for both sets of rats during the last half of the series.

The results of this experiment correspond in general with the results for group I, and again no noticeable influence of forced activity upon maze learning is shown. The control animals did not prove superior to the activity animals in either time or error scores.

C. Group III. The animals of group III were 8 young males, 100 days old at the beginning of the experiment. The control and activity rats were equated for weight and spontaneous activity as the preceding groups had been. Before the maze-learning experiment was undertaken, all of the activity animals were daily given small amounts of forced exercise in the drums. This was done to orient the rats to the drums. The activity rats of this group received 1500 revolutions of forced running daily throughout the 20 trials of the standard maze-learning series. Experimental conditions were the same as for Groups I and II, with the exception of the increased amount of forced activity.

The maze pattern was again changed so that it was identical with the pattern learned by the animals of group I. In addition to the standard series of 20 trials, 5 additional trials were given, in which the exercise was increased progressively by 500 revolutions each day. On the twenty-fifth trial, the activity rats received 4000 revolutions. This number of revolutions forced the animals to travel a distance of approximately 14,600 feet. One activity animal died in the revolving drum at this trial.

The data obtained with group III are presented in table 4. It may readily be seen from table 4 that there is a great reduction in time consumed and errors made by both sets of animals in the last five trials, as compared with the first five trials. Such reduction indicates the occurrence of the process of learning in both groups.

Comparison of the error scores in table 4 for control and activity animals shows that throughout the series the two groups tended to remain about equal in performance. When the two groups of rats commenced the series, they made approximately the same number of errors. During the first 8 trials there is a definite tendency to reduce the number of errors. In the middle portion of the series there is a continued but slight reduction of errors by both groups. From the thirteenth to the twentieth trials, the scores remain low but do not vary. From the twenty-first to the twenty-fifth trial, during which time the forced exercise was increased daily, the activity animals showed a tendency to make more errors than the controls. During the last few trials of the learning series, the control group appeared to be slightly superior, but analysis of the individual records revealed that this difference is not reliable.

The time scores presented in table 4 are less easily analyzed. Although the activity animals were much slower on the first trial than were the control rats, they soon began to run the maze more rapidly. They did not, however, equal the speed of the control rats until the fourth trial. From this point until the twenty-fourth trial, the time scores for the activity rats tended to be better than those of the control rats. On the twenty-fifth trial the average time of the activity rats increased greatly. This in-

crease is due mainly to one rat, which required over six minutes to traverse the maze. The rat was in a state of exhaustion when removed from the activity drum. It is quite possible that the marked difference in time scores of the two groups at the beginning of the series was due to lack of adaptation to forced exercise

TABLE 4

Average time and errors for group III

TRIAL	TIME IN SECONDS		ERRORS	
	Activity	Control	Activity	Control
1	1166.2	105.0	3.75	4.00
2	625.2	67.0	4.00	2.50
3	256.5	83.2	2.75	3.75
4	32.5	69.5	2.25	2.25
5	29.0	68.0	2.75	2.25
6	18.5	51.5	1.50	2.75
7	15.7	34.0	1.50	1.75
8	13.0	18.2	1.25	1.25
9	12.2	20.2	1.25	1.75
10	13.6	25.2	1.25	1.25
11	11.8	19.7	1.00	1.25
12	11.7	19.2	1.25	1.50
13	10.5	13.7	0.75	0.50
14	10.5	15.2	0.75	0.50
15	11.3	12.7	0.75	0.50
16	10.5	13.5	0.75	0.50
17	12.6	17.0	0.75	0.75
18	10.6	9.3	0.75	0.25
19	12.4	11.7	0.50	0.00
20	10.5	9.9	0.75	0.50
21	7.6	10.4	0.50	0.75
22	10.7	11.6	0.75	0.25
23	17.7	9.2	1.25	0.25
24	15.7	11.8	0.75	0.50
25	151.0	14.0	1.33	0.75

on the part of the activity rats. These animals were given a rather large amount of forced activity with very little practice in compulsory running. For the first 3 trials, the rats showed definite signs of exhaustion upon removal from the activity cages. Foot injuries, caused by friction with the wire mesh of the activity drums, were numerous. The injuries sustained also could

easily account for their slowness in the maze. These animals, under the conditions specified, when placed in the maze showed little activity, often sitting for long periods of time apparently recovering from fatigue. The exercised animals ran the maze more rapidly when they recovered from their injuries. A minor change in the apparatus enabled the experimenter to prevent occurrence of additional foot injuries. After the third trial, the periphery of each drum was lined with linoleum. It should be noted, however, that during the period when the time scores of the activity rats were very poor, the error scores were exceptionally good.

The increased activity given in the additional 5 trials (twenty-first to twenty-fifth) produced no consistent effect upon maze performance. The additional daily exercise produced definite symptoms of fatigue in the rats. Upon removal from the drums they showed increased respiration, panting, temperature changes, and accelerated heart rate. They frequently failed to react to ordinary auditory and tactual stimuli. As already noted, one of the activity animals died as a result of the increased exercise.

Records of body weights taken at the completion of the learning series were compared with records of weights obtained at the beginning of the series. It was found that both activity and control animals lost considerable weight, but the weight loss of the activity rats was markedly greater than that of the control rats. The percentages of weight lost were 20 per cent and 6.1 per cent for the two groups, respectively.

The results on the animals of group III can only be interpreted as indicating that the amount of forced exercise given had no significant effect upon learning. It is to be noted that up to this point in the experiment there was no evidence to support the investigator's original but tentative hypothesis, namely, that forced activity should show a deleterious effect on maze learning.

D. Group IV. It had been observed in the experiments with groups I, II and III that the activity animals consistently lost more weight during the maze-learning period than did the control animals. Since the greater weight loss on the part of the activity animals might have affected indirectly the general ac-

tivity of these animals in the maze, it was decided that certain modifications should be made in the experimental conditions. The major modification was a change in the type of motivation used for maze learning.

Various methods for motivating maze learning were tested before the rats of group IV were started on the maze problem. Unsuccessful attempts were made to use cold water or electrical current passing through water as incentives to maze learning. Finally, what appeared to be a highly successful method of motivating the animals was devised. A large grid was constructed of lengths of Number 14 bare copper wire one-quarter inch apart, stretched on a wooden frame, 5 feet wide and 12 feet long. The bottom was removed from the original maze and the maze placed upon the grid. The animals were compelled to run or walk on the wires. Current passed through their bodies continually from the time they were placed in the maze until they reached the escape box. The electrical hook-up is shown in figure 2. Preliminary work with this set-up indicated that it would prove satisfactory. This type of motivation was employed with the animals of group IV and all succeeding groups.

Another modification in the general procedure was the keeping of accurate records on the daily food and liquid intake of each animal. This was easily managed, as the rats were kept in individual living cages. The animals continually had access to a modified Steenbock ration, plain water, and a solution of sugar and water. The arrangement, therefore, permitted the animals to derive calories from two sources: the regular ration and the sugar solution. The modified diet was composed of the following ingredients in the proportions indicated:

	per cent
Yellow corn meal	77.45
Linseed meal	7.50
Ground alfalfa	6.00
Powdered whole milk	6.25
Crude casein	2.50
NaCl	0.15
$CaCO_3$	0.15
Total	100.00

The animals composing group IV were females, ranging in age from 215 to 225 days at the beginning of the experiment. Five-day spontaneous activity norms were established for all 8 animals. The control and activity groups were equated on a basis of spontaneous activity, age, and litters. The activity animals were

TABLE 5

Average time and errors for group IV

TRIAL	TIME IN SECONDS		ERRORS	
	Activity	Control	Activity	Control
1	272.7	505.0	4.25	3.75
2	119.2	379.5	3.50	5.25
3	63.2	225.7	1.75	3.75
4	48.7	433.2	2.25	3.00
5	57.0	326.5	2.00	5.50
6	51.4	217.5	2.25	4.25
7	23.9	148.7	1.50	3.25
8	35.9	99.7	1.75	2.75
9	19.5	80.7	1.75	2.50
10	14.5	80.7	1.00	2.50
11	14.7	91.2	0.75	2.75
12	12.3	49.2	0.75	1.50
13	14.5	47.0	0.75	2.00
14	17.3	38.7	1.00	1.50
15	13.9	37.9	0.75	1.50
16	17.4	49.5	0.75	1.75
17	17.4	53.6	0.00	1.00
18	19.2	38.2	0.50	1.00
19	25.2	31.3	0.50	0.50
20	15.1	29.7	0.00	1.00
21	15.5	21.9	0.00	1.00
22	16.8	23.7	0.00	0.75
23	14.3	24.0	0.00	0.50
24	13.8	20.5	0.00	0.75
25	16.1	23.8	0.00	0.75
26	10.7	29.0	0.00	0.75

forced to run 2400 revolutions, at 20 revolutions per minute, daily throughout the experiment. One trial per day for 20 days was given on the maze. This series was extended to include 6 additional trials, since the groups differed somewhat with respect to error scores at the twentieth trial. It was thought that the

additional trials might eliminate this difference. On the twenty-sixth trial, the rats were allowed to run the maze without shock.

The results of the maze learning of group IV are presented in table 5 and figures 5 and 6. It may be seen that both sets of rats show a progressive reduction in both time consumed and errors made during the series. A comparison of the error scores

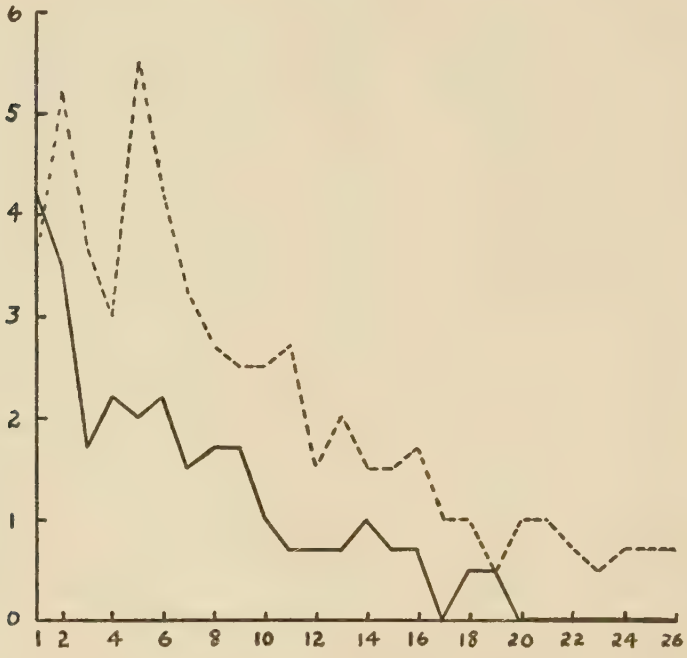

FIG. 5. AVERAGE ERROR CURVES FOR GROUP IV

Successive trials are indicated on the abscissa. Average error scores per trial are shown along the ordinate. The solid line represents the average number of errors per trial made by the activity animals. The broken line represents the average number of errors per trial made by the control animals.

shows that the activity animals tended to make fewer errors on the average throughout the learning series. The time scores indicate that the activity animals were also faster in the maze.

Error curves are presented in figure 5. Both the control and activity animals began the series at about the same level. The activity group showed a much more rapid elimination of errors than did the control group. In the middle part of the series the

curves for the two groups tend to run parallel, but the curve for the activity animals is consistently lower than that for the control animals. Both of the curves show some fluctuation, but the

FIG. 6. AVERAGE TIME CURVES FOR GROUP IV

Successive trials are indicated on the abscissa. Average time scores (in seconds) per trial are shown along the ordinate. The solid line represents the average time per trial consumed by the activity animals. The broken line represents the average time per trial consumed by the control animals.

greater fluctuations appear for the control rats. During the last trials, the curves for both groups tend to flatten out and maintain a constant level. The curve for the activity group shows errorless

performance for the group as a whole during the last 6 trials and indicates the superiority of the activity animals.

The average time curves, shown in figure 6, present relations similar to those of the error curves of group IV. Both curves show a marked drop during the first trials, although the activity group was much faster on the initial trial. The curve for the activity group remains considerably lower than that for the control group during the first half of the series. After the twelfth trial, the curves tend to flatten out, but the curve for the control group never reaches the low level of the curve for the activity group. On the last 7 trials, the curves approximate each other, but the curve of the activity rats remains below that of the control rats. At no point in the series was the average performance of the control group as good as that of the activity group.

Accurate measurements taken every five days showed that the rats on the average lost very little weight and that the small loss which did occur was about the same for both control and activity animals.

In summarizing the results on group IV, it may be noted that, as measured by both time and errors, the animals given forced activity were slightly superior to the control animals. Such results suggest that compulsory exercise has a facilitating rather than a deleterious effect upon maze learning.

E. Group V. The animals composing group V were 8 females, 130 to 150 days old when the experiment was begun. Control and activity groups were equated as in the preceding experiments.

In general, the experimental procedure for group V was the same as for group IV. The same maze problem, with the same type of motivation, was employed. Data on food and liquid intake were likewise obtained on all rats of this group throughout the experimental period.

One change in procedure was made for this group, because no significant difference in maze learning had been found between the control and activity animals in the previous groups. It was thought that absence of a real difference might be due to the fact that the activity animals had partially learned the maze before the forced activity became effective.

The activity animals of group V were given forced exercise for 34 days prior to their first trial in the maze. These animals were adapted gradually to the forced activity. During the first few days of the adaptation period, only small amounts of forced exercise were given daily. On the tenth day the activity animals were given the maximum amount of exercise, 3000 revolutions at the rate of 20 revolutions per minute. This amount of forced activity was maintained daily throughout the learning series.

Before the maze-learning series was begun, one of the activity rats died while in the revolving cage. Exhaustion was apparently the cause of death. It was decided to continue the learning series with the other 3 activity animals. In the data which follow, the averages for the activity rats were derived from the scores of 3 animals instead of 4.

The findings with group V are presented in table 6. The data indicate performances characteristically similar to those of group IV. The figures of table 6 show a marked reduction in time and errors for both control and activity groups.

On the initial trial, the control animals made more errors than the activity animals. Errors were eliminated rapidly by both groups, and after seven trials the error scores showed but slight improvement. At no point in the series was the error score of the control animals as good as that of the activity animals. The difference in error scores was rather marked.

The control and activity rats made about the same average time scores on the first trial in the maze. The scores of the activity animals immediately improved. The time scores for the control animals, however, varied considerably before they definitely improved. During the middle portion of the series, the scores of the two groups tended to remain fairly constant, although those of the activity group were markedly lower than those of the control rats. The same relationship holds for the final trials, except that the time scores for the control animals approached those of the activity animals more closely.

Both time and error records obtained on group V indicate that the rats given forced activity were somewhat superior to the control animals in maze learning.

F. Group VI. The animals of group VI were 8 male brothers, 150 days old when the experiment began. The activity rats of this group were given compulsory exercise in increasing amounts from day to day throughout the learning series. This procedure was decided upon in order to test the general notion that adaptation to fatigue occurs when the same amount of activity is given daily over a period of time. Observations on the previous groups

TABLE 6

Average time and errors for group V

TRIAL	TIME IN SECONDS		ERRORS	
	Activity	Control	Activity	Control
1	501.7	540.0	5.33	8.25
2	347.7	816.2	4.33	8.00
3	119.0	385.5	2.33	9.00
4	31.3	281.2	2.00	6.75
5	41.0	162.0	1.66	2.50
6	49.3	248.5	1.33	3.25
7	62.3	146.2	1.33	2.75
8	40.3	153.5	1.00	3.25
9	24.0	140.2	0.66	3.75
10	18.9	164.5	0.00	2.50
11	15.9	124.5	0.33	2.75
12	24.5	114.0	0.00	2.75
13	22.8	83.5	0.33	2.25
14	33.0	93.2	0.66	2.50
15	39.2	62.2	0.33	2.25
16	28.0	72.7	0.33	1.75
17	25.0	63.9	0.66	1.50
18	29.2	41.7	0.66	1.75
19	19.0	39.6	0.33	1.25
20	31.0	36.8	0.66	1.50
21	16.3	41.8	0.00	1.75
22	22.0	36.8	0.33	1.25

seemed to confirm this theory, since the fatigued animals appeared to be exhausted when they were first compelled to run but showed less marked signs of exhaustion after several days of exercise.

On the first day of the experiment, the activity animals were given 600 revolutions at 10 revolutions per minute. The second day, the amount of activity was the same, but the speed was

doubled. Throughout the remainder of the experiment, the forced exercise was increased each day by steps of 200 to 500 revolutions. On the last trial, the twentieth, these animals were given 5000 revolutions at a rate of 20 revolutions per minute. One of the activity animals died of exhaustion in the revolving drum on the eighteenth day, when 4000 revolutions were given.

The results with respect to the maze-learning ability of the ac-

TABLE 7

Average time and errors for group VI

TRIAL	TIME IN SECONDS		ERRORS	
	Activity	Control	Activity	Control
1	1358.2	936.2	12.00	8.25
2	398.7	411.7	6.00	4.75
3	170.0	276.5	4.25	3.25
4	120.7	162.5	3.25	3.25
5	49.7	225.0	1.75	3.50
6	67.2	149.0	2.75	4.50
7	47.2	141.2	2.75	3.25
8	20.0	119.2	2.75	3.25
9	19.0	84.0	2.50	2.00
10	14.0	83.7	1.50	2.25
11	12.0	105.2	1.25	2.25
12	15.2	69.7	1.75	1.75
13	12.6	81.0	1.50	2.00
14	18.0	67.2	1.50	1.25
15	14.1	72.5	1.25	1.25
16	12.4	61.7	1.25	1.50
17	11.5	69.7	0.75	1.25
18	10.5	43.3	0.00	1.25
19	10.1	48.0	0.33	1.00
20	8.8	37.0	0.00	0.75

tivity and control animals of group VI are presented in table 7. These results are in accord with the results obtained with previous groups. From table 7 it is evident that learning occurred in both activity and control groups, since both error and time scores improved greatly throughout the series. The activity animals were slower and made more errors on the first trial than did the control animals. Errors were eliminated by the con-

trol and activity animals at about the same rate. At no point in the series did the average error scores differ greatly. The activity rats tended to make slightly better time scores than the control animals for the greater part of the series.

The results obtained with this group of rats give evidence that forced activity, in the amount used, has no pronounced effect upon maze learning. As judged by both time and error scores, the activity animals were slightly superior to the control animals.

TABLE 8

Average time and errors for all animals on each trial

TRIAL	TIME IN SECONDS				ERRORS			
	Activity (N = 23)		Control (N = 24)		Activity (N = 23)		Control (N = 24)	
	Average	*S. D.*	*Average*	*S. D.*	*Average*	*S. D.*	*Average*	*S. D.*
1	605.1	562.60	374.4	396.37	5.13	4.27	5.16	2.88
2	268.9	317.75	292.8	407.52	3.91	2.74	4.50	3.19
3	120.1	134.21	172.8	206.45	2.69	1.34	4.04	3.84
4	50.9	42.99	168.5	180.83	2.65	1.10	3.54	2.36
5	36.1	20.36	137.5	144.75	1.91	1.02	3.00	2.08
6	38.7	33.59	118.0	192.92	1.78	1.54	3.21	1.96
7	30.3	33.30	86.4	107.79	1.65	1.05	2.58	1.76
8	26.4	24.78	71.0	84.78	1.65	1.49	2.16	1.32
9	19.2	12.54	59.5	74.98	1.69	1.27	2.16	1.41
10	18.2	14.22	65.0	90.02	1.13	1.07	2.00	1.29
11	14.3	7.02	61.4	81.73	1.04	1.04	1.92	1.55
12	16.9	15.25	46.1	70.38	1.13	1.15	1.50	1.12
13	13.8	9.82	41.7	57.52	0.91	0.93	1.54	1.26
14	15.4	15.17	39.8	57.22	0.83	0.86	1.37	1.29
15	15.5	19.01	34.1	44.73	0.69	0.81	1.16	1.14
16	14.3	16.80	35.9	39.11	0.74	0.79	1.12	1.06
17	13.5	7.81	37.5	48.18	0.43	0.66	1.08	0.76
18	14.5	11.88	25.3	26.70	0.59	0.73	0.83	0.92
19	14.0	11.27	25.2	25.46	0.50	0.84	0.75	0.83
20	13.8	10.25	22.1	22.20	0.45	0.73	0.75	0.83

G. Combined Groups. Since the number of rats in any one of the experimental groups was small, the control animals and the activity animals of all six groups have been arbitrarily combined to form two large groups (control and activity, respectively). This procedure may be questioned, since the experimental conditions were not identical for all groups, some groups being given

greater amounts of forced exercise and more maze trials than others. It is believed, however, that the separate experiments were sufficiently similar to permit the type of treatment here pro-

TABLE 9

Average time and errors for all animals on all trials

ANIMALS	TOTAL TIME (FIRST 20 TRIALS)		TOTAL ERRORS (FIRST 20 TRIALS)	
	Activity	Control	Activity	Control
1	420.8	455.7	15	44
2	558.2	404.6	31	31
3	671.0	751.0	60	48
4	888.6	531.0	32	52
5	272.0	226.3	11	17
6	427.0	221.6	28	19
7	1026.5	308.7	30	19
8	268.1	409.7	16	22
9	1623.2	563.0	31	33
10	2966.0	350.4	46	32
11	1520.6	900.5	29	26
12	3071.0	923.2	15	28
13	860.1	3169.3	14	41
14	667.0	3785.0	30	76
15	697.0	2198.0	26	54
16	1270.0	2704.0	41	33
17	1458.0	8398.0	16	97
18	617.4	2215.2	20	46
19	2434.4	957.0	37	52
20	2446.4	3512.0	46	86
21	2976.0	2378.4	65	18
22	1551.8	3360.0	37	79
23	*	1674.0	*	45
24	*	5567.0	*	68
Average	1304.10	1915.15	30.73	44.41
S. D.	900.66	1958.90	14.18	22.31
P. E.$_M$	132.65	275.26	2.09	3.14
D/P.E.$_{Diff.}$	1.99		3.63	

* Two activity animals died before maze series was completed.

posed. It was thought that with such treatment it might be shown whether the slight differences in maze performance found between the control and activity animals of the individual groups

would tend to become negligible or more significant. The time and error scores for only the first 20 maze trials have been considered.

The data for the combined groups, in the form of average error and time scores, are presented in tables 8 and 9 and figures 7 and 8. The average scores, given in table 8, and the learning curves,

FIG. 7. AVERAGE ERROR CURVES FOR COMBINED GROUPS

Successive trials are indicated on the abscissa. Average error scores per trial are shown along the ordinate. The solid line represents the average number of errors per trial made by the activity animals. The broken line represents the average number of errors per trial made by the control animals.

shown in figures 7 and 8, demonstrate more clearly the differences in performance indicated in the data for the individual groups. The average scores of the activity animals are consistently, but not markedly, better than those of the control animals in respect to both time and errors. It will be noted that the variability of the individual scores tends to be large.

In table 9 are presented total time and error scores for all rats

for the first 20 trials of the maze series. It may be seen that the activity animals on the average required less time and made fewer errors for the 20 trials than did the control animals. The time scores of 17 of the 22 activity animals are superior to the average time score for the control group, and the time scores of

FIG. 8. AVERAGE TIME CURVES FOR COMBINED GROUPS

Successive trials are indicated on the abscissa. Average time scores (in seconds) per trial are shown along the ordinate. The solid line represents the average time per trial consumed by the activity animals. The broken line represents the average time per trial consumed by the control animals.

13 of the 24 control animals are better than the average time score for the activity group. The error scores of 16 of the activity animals are better than the average error score of the control animals, while the error scores of only 4 of the control animals are superior to the average error score for the activity group. Statistical treatment of the data reveals a high degree of variability

in individual time and error scores for both control and activity groups. Because of this variability, the average scores are not highly reliable.

With respect to time scores, the ratio of the difference in averages to the probable error of the difference is 1.99. This ratio reveals clearly that the difference in average time scores for the two groups is not a reliable difference. On the other hand, the ratio of the difference in average error scores to the probable error of the difference is 3.63. This ratio indicates that the difference in average error scores may be considered statistically reliable, the activity animals having error scores superior to those of the control animals. As noted earlier in this paper, it is believed that error scores provide a more reliable measure of maze learning ability than do time scores. However, since the experimental procedure was not identical for the six individual groups, and since these groups were combined arbitrarily for statistical treatment, extreme caution must be maintained in arriving at a definite conclusion.

Statistical treatment of the data in table 9 permits the interpretation that, as measured by time scores, forced activity, under the conditions set up, had no harmful influence on maze learning and that, as measured by error scores, forced activity had a slightly beneficial effect upon maze performance. The results obtained in the present experiment substantiate in general those of Corey (10), who found that certain amounts of forced exercise had a slightly beneficial effect upon maze learning by rats.

SUMMARY AND CONCLUSIONS

An investigation has been made of the effect of forced activity on the maze-learning ability of white rats. The maze used was a six-section, multiple-U maze, constructed of redwood.

Forty-eight white rats were used, in groups of 8; 4 of each group were given forced activity, and 4 were used as controls. The separate groups varied in age and sex, but for any given group the activity and control animals were equated with respect to these factors and also with respect to spontaneous activity, litter, and weight.

Maze learning was measured in terms of time scores and error scores. One trial per day for at least 20 days was given in the maze.

The activity animals of each of the 6 groups were given forced exercise daily. These animals were exercised in motor-driven revolving cages of the type ordinarily used to record spontaneous activity. The drums of the cages were 14 inches in diameter. The forced activity given varied in amount and rate from group to group.

Food served as the incentive to maze learning for 3 of the groups. The animals of the other 3 groups were motivated by punishment in the form of electric shock.

On the whole, the results obtained from all 6 groups were consistent. Time and error measurements taken during the learning series indicated learning by both activity and control animals in all groups. In no case was a reliable difference found between average time scores for control and activity animals. In general, the activity animals tended to be slightly superior to the control animals in error scores. This difference, favoring the activity animals, was found to be statistically reliable when the groups were combined.

It is believed that the experimental results obtained in the present investigation justify the following conclusions:

1. As measured by time scores, forced activity of the amounts and at the rates given had no deleterious effect on the maze performance of white rats.

2. As measured by error scores, forced activity of the amounts and at the rates given had a slightly beneficial effect on the maze learning of white rats.

REFERENCES

(1) Abbot, A. C., and Gildersleeve, N.: The influence of muscular fatigue and of alcohol upon certain of the normal defenses. Univ. Pa. Med. Bull., 1910, **23**, 169-181.

(2) Armsby, H. P.: The nutrition of farm animals. 1917, New York. Macmillan Co.

(3) Bailey, A.: Amer. Jour. Hyg., 1925, **5**, 175.

(4) Boinet, M. E.: Resistance a la fatigue de 11 rats decapsules depuis cinq et

six mois. 1895, Comptes Rendus de la Societe de Biologie, 10e Series, No. 2, p. 273.

(5) Boinet, M. E.: Nouvelles recherches sur la resistance a la fatigue de rats decapsules depuis longtemps. 1895, Comptes Rendus de la Societe de Biologie, 10e Series, No. 2, p. 325.

(6) Boycott, A. E., and Price-Jones, C.: Experiments on the influence of fatigue on infection. Jour. Pathol. and Bacteriol., 1926, **29,** 87-95.

(7) Bugbee, E. P., and Simond, A. E.: The increase of voluntary activity of ovariectomized albino rats caused by injections of ovarian follicular hormone. Endo., 1926, **10,** 349-359.

(8) Charrin and Roger: 1890, La Semaine Medical, 29.

(9) Charrin and Roger: Contribution a l'etude experimentale du surmenage, son influence sur l'infection. Arch. de Physiol., Norm. et Path., 1890, **2,** 273-283.

(10) Corey, S. M.: The relationship between compulsory physical exercise and the ability of the white rat to learn and relearn an elevated skeleton maze. Jour. Comp. Psychol., 1931, **11,** 291-318.

(11) Dorcus, R. M., and Gray, W. L.: The rôle of kinesthesis in retention by rats. Jour. Comp. Psychol., 1932, **13,** 447-451.

(12) Dorcus, R. M., and Gray, W. L.: The effectiveness of food and electric shock in learning and retention by rats when applied at critical points in the maze. Jour. Comp. Psychol., 1932, **14,** 191-218.

(13) Dunlap, K.: Standardizing electric shocks for rats. Jour. Comp. Psychol., 1931, **12,** 133-135.

(14) Durrant, E. P.: Studies on vigor. I. Effect of adrenal extirpation on activity of the albino rat. Amer. Jour. Physiol., 1924, **70,** 344-350.

(15) Durrant, E. P.: Relation of hysterectomy of long standing to voluntary activity in the white rat. Amer. Jour. Physiol., 1931, **97,** 519. (An abstract from: Proceedings of the American Physiological Society, 1931.)

(16) Gans, H. M.: Studies on vigor. XIV. Effect of fractional castration on the voluntary activity of male albino rats. Endo., 1927, **11,** 145-148.

(17) Hausmann, M. F.: The behavior of albino rats in choosing food and stimulants. Jour. Comp. Psychol., 1932, **13,** 279-309.

(18) Hitchcock, F. A.: Studies in vigor. V. The comparative activity of male and female albino rats. Amer. Jour. Physiol., 1925, **75,** 205-210.

(19) Hitchcock, F. A.: The effect of the luxus consumption of meat upon the voluntary activity and growth of the albino rat. Amer. Jour. Physiol., 1926-27, **79,** 206-217.

(20) Hoskins, R. G.: Studies on vigor. II. The effect of castration on voluntary activity. Amer. Jour. Physiol., 1925, **72,** 324-330.

(21) Hoskins, R. G.: Studies on vigor. XVI. Endocrine factors in vigor. Endo., 1927, **11,** 97-105.

(22) Howells, T. H.: An electrical stimulus-apparatus. Amer. Jour. Psychol., 1931, **43,** 122-123.

(23) Jenkins, T. N., Warner, L. H., and Warden, C. J.: Standard apparatus for the study of animal motivation. Jour. Comp. Psychol., 1926, **6,** 361-382.

(24) Keith, M. H., and Mitchell, H. H.: The effect of exercise on vitamin requirements. Amer. Jour. Physiol., 1923, **65**, 128–138.
(25) Morpurgo, B.: "Ueber Activitäts-Hypertrophie der will kürlichen Muskeln." Arch. Path. Anat., 1897, **150**, 522–554.
(26) Muenzinger, K. F., and Mize, R. H.: The sensitivity of the white rat to electric shock—threshold and skin resistance. Jour. Comp. Psychol., 1933, **15**, 139–148.
(27) Nichols, E. E., and Spaeth, R. A.: The relation between fatigue and the susceptibility of guinea pigs to infections of Type I pneumococcus. Amer. Jour. Hyg., 1922, **2**, 527–535.
(28) Oppenheimer, E. H., and Spaeth, R. A.: The relation between fatigue and the susceptibility of rats towards a toxin and an infection. Amer. Jour. Hyg., 1922, **2**, 51–66.
(29) Price-Jones, C.: The effect of exercise on the growth of white rats. Quar. Jour. Exper. Physiol., 1927, **16**, 61–67.
(30) Richter, C. P.: A behavioristic study of the activity of the rat. Comp. Psychol. Mono., 1922, **1**, No. 2, 1–55.
(31) Richter, C. P.: The rôle played by the thyroid gland in the production of gross body activity. Endo., 1933, **17**, 73–87.
(32) Richter, C. P., and Wang, G. H.: New apparatus for measuring the spontaneous motility of animals. Jour. Lab. and Clin. Med., 1926, **12**, 289–292.
(33) Seham, M., and Seham, G.: An experimental study of chronic fatigue. Amer. Jour. Dis. Child., 1929, **37**, 997–1006.
(34) Shirley, M.: Studies of activity. I. Consistency of the revolving drum method of measuring the activity of the rat. Jour. Comp. Psychol., 1928, **8**, 23–38.
(35) Shirley, M.: Studies in activity. II. Activity rhythms; age and activity; activity after rest. Jour. Comp. Psychol., 1928, **8**, 159–186.
(36) Slonaker, J. R.: The normal activity of the white rat at different ages. Jour. Comp. Neur. and Psychol., 1907, **17**, 342–359.
(37) Slonaker, J. R.: Description of an apparatus for recording the activity of small mammals. Anat. Record, 1908, **2**, 116–122.
(38) Slonaker, J. R.: The normal activity of the albino rat from birth to natural death, its rate of growth and the duration of life. Jour. Anim. Behav., 1912, **2**, 20–42.
(39) Slonaker, J. R.: The effect of pubescence, oestruation and menopause on the voluntary activity in the albino rat. Amer. Jour. Physiol., 1924, **68**, 294–315.
(40) Slonaker, J. R.: Effect on different per cents of protein in the diet. II. Spontaneous activity. Amer. Jour. Physiol., 1931, **96**, 557–561.
(41) Slonaker, J. R., and Robertson, D. I.: The effect of compulsory work during gestation on the mother and young. Amer. Jour. Physiol., 1925, **72**, 502–548.
(42) Spaeth, R. A.: An experimental investigation of the supposed relation between good physical condition and natural resistance to infection. Amer. Jour. Hyg., 1925, **5**, 839–853.

(43) Steenbock, H.: A satisfactory ration for stock rats. Science (New Series), 1923, **58**, 449-450.
(44) Stewart, C. C.: Variations in daily activity produced by alcohol and by changes in barometric pressure and diet, with a description of recording methods. Amer. Jour. Physiol., 1898, **1**, 40–56.
(45) Tolman, E. C., and Nyswander, D. B.: The reliability and validity of maze measures for rats. Jour. Comp. Psychol., 1927, **7**, 425–460.
(46) Vallardi: Pathologica, 1912, **4**, 279.
(47) Wang, G. H.: The relation between spontaneous activity and oestrous cycle in the white rat. Comparat. Psychol. Mono., 1923, **2**, No. 6, 1–27.
(48) Warden, C. J., and Schneck, W. R.: A comprehensive survey of the experimental literature on animal retention. Jour. Genet. Psychol., 1929, **36**, 1–20.
(49) Warner, L. H., and Warden, C. J.: The development of a standard animal maze. Arch. Psychol., 1927, **15**, 1–35.

VITA

Wendell Lafon Gray; born, November 30, 1908, Baltimore, Maryland; attended elementary and high schools, Savannah, Georgia; attended Lynchburg College, Lynchburg, Virginia, 1926–27; Oglethorpe University, Atlanta, Georgia, 1927–28; Johns Hopkins University, Baltimore, Maryland, 1928–30; received Bachelor of Arts degree, Johns Hopkins University, 1930; graduate student and Student Assistant, Department of Psychology, Johns Hopkins University, 1930–33; member of Kappa Sigma, Sigma Xi, and Phi Beta Kappa.

Publications:

(1) The Rôle of Kinesthesis in Retention by Rats. (With Dr. Roy M. Dorcus.) Jour. Comp. Psychol., 1932, 13, 447–451.

(2) The Effectiveness of Food and Electric Shock in Learning and Retention by Rats when Applied at Critical Points in the Maze. (With Dr. Roy M. Dorcus.) Jour. Comp. Psychol., 1932, 14, 191–218.